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THE HENRY DRAPER MEMORIAL.

THE third annual report, just published, shows that the researches which constitute the Henry Draper Memorial have consisted for the last three years in the photographic study of the spectra of the stars. While this subject will continue to be the principal one under investigation, Mrs. Draper has decided to extend the field of work undertaken so as to include the study of the other physical properties of the stars by photography. The first research undertaken is now rapidly approaching completion, the plans for the study of the southern stars have been matured, and this study will soon be begun. The detailed study of the spectra of the brighter stars is making progress, and a large piece of photometric work will soon be undertaken with a new telescope.

The Bache telescope, which has an 8-inch photographic doublet as an objective, is used for the catalogue of spectra of bright stars. The photographs cover the entire sky north of —25°, with exposures of about five or ten minutes. About 28,000 spectra of 10,800 stars have been examined, including nearly all stars visible in Cambridge, of the seventh magnitude or brighter. The catalogue is now nearly ready for the printer.

In November, 1888, the photographs required to cover the sky north of the equator for the catalogue of spectra of faint stars were nearly finished. It was expected that in two months the observations would be completed. The telescope, which was the same as that used in the previous research, was, however, wanted for photographing the solar eclipse of Jan. 1, 1889. It was accordingly sent to Willows, Cal., where it was mounted, and the greater portion of the remaining photographs were taken there. It was then sent to Peru. The few remaining photographs, including the repetition of those found on further examination to be unsatisfactory, will be taken in Peru. The sky from —25° to the south pole will be covered for bright stars as well, and the resulting photographs sent to Cambridge and reduced, as in the case of the northern stars. The advantages of discussing all stars from the north to the south pole according to one system are very great, and are here secured for the first time in so extensive an investigation. If no unforeseen difficulty arises, the photographs will all be completed during the next two years.

The 11-inch refractor, with one, two, or four large prisms over its objective, has been employed in the detailed study of the spectra of the brighter stars throughout nearly every clear night, until stopped by the morning twilight: 686 photographs have been taken, most of them with an exposure of two hours. With the present photographic plates, about 570 stars north of —30° are bright enough to be photographed with one prism, 170 of them with two prisms, and 87 of them with four prisms. To obtain the best possible result, some of the photographs must be repeated many times. The difficulty is increased by the invariably hazy appearance of the lines in some spectra, like that of *α Aquilæ*, which was at first attributed to poor definition of the photograph. It is expected that the work will be completed during the next year by original or repeated photographs of 228 stars with one prism, of 64 with two, and of 12 with four. In general, stars as bright as the fourth magnitude can be satisfactorily photographed with one prism, the spectra obtained being about an inch long. Fainter stars, if of a bluish color, give sufficiently distinct images, in some cases good results being obtained with stars of the seventh magnitude. For example, fourteen stars in the Pleiades are well photographed with this apparatus. With four prisms, much longer spectra are obtained, and many more lines are visible. But certain differences in the character of the spectra are better shown with the smaller dispersion. Numerous photographs have been taken of the variable stars *o Ceti* and *β Lyræ*. The changes in the spectrum of the latter star seem to be undoubted; those of *o Ceti*, if any, to be slight. Various peculiarities in the spectra of individual stars have been detected. One photograph of *ζ Ursæ Majoris* shows the K line distinctly double, and others show it single. Many photographs will be required to determine the law of its variation, if this is due to changes in the star itself. Bright lines were detected in the spectrum of *φ Persei*, putting it in a class in which only two or three other stars are known to fall. In the double star *β Cygni* the two components have spectra of different types,—an important consideration in the theories regarding their formation. The brighter component is of the second type; the fainter, of the first.

Ordinary photographic plates are not sensitive to rays of much greater wave-length than the F line, or 486. By staining the plates with various coal-tar products, the range of sensitiveness may be greatly extended. With erythrosine, the spectrum extends to the wave-length 590. The sodium line D is distinctly seen to be double in the photographs of *α Bootis* and *α Aurigæ*. Various experiments were also made with cyanine, but the plates were not sufficiently sensitive to give good results. The entire length of the spectrum with four prisms, including the portion obtained by erythrosine, is about six inches and a half.

A beginning has been made of the measures of the positions of the lines in the spectrum. A scale of fortieths of an inch has been ruled on glass, and the positions of the lines read off with the aid of a magnifying-glass. Twelve of the photographs of *α Canis Majoris* have been studied in this way. The spectrum of this star is traversed by the hydrogen lines, which are strong, and by other lines which are so faint that they are only visible when the dispersion is large and the definition good. The catalogue thus formed contains about 320 lines. The average deviation of the measures of the same line on different plates is about 0.05 of a millionth of a millimetre, or 0.05 centimetres on the scale of Angström's map. If the line occurs in the solar spectrum, these measures will generally identify it. In other cases the exact position

must be determined by a dividing-engine. If a line can be distinctly seen, its wave-length can probably be thus determined with as great accuracy as that of the position of the solar lines on the map of Angström. In the spectrum of *α Bootis* 140 lines are visible between the D and F lines.

The classification of this large number of spectra is a matter of no little difficulty. Slight differences exist in many stars, and certain stars appear to hold an intermediate position, so as to render a rigorous division into classes impossible. On the other hand, many stars appear to have identical spectra. The first step will be to arrange the stars in groups, and then compare the best defined spectra of different groups. A minute discussion and the measurement of wave-lengths will be necessary only in the investigation of a comparatively small number of spectra.

The 28-inch reflecting telescope constructed by Dr. Draper was assigned to the work on faint stellar spectra. During the first six months of the year a careful study was made of this problem, and the difficulties encountered bore evidence of the skill of Dr. Draper in obtaining good results with this telescope. The best method of using this instrument seemed to be a modification of the form first tried by Dr. Draper, — a slit spectroscope from which the slit had been removed. The rays from the mirror were rendered parallel by a concave lens which replaced the objective of the collimator. As this lens had the same focal distance as the objective of the observing telescope, it was not necessary that either should be achromatic. After long trials with this and other forms of apparatus, a spectrum was at length obtained showing good definition. As the results were not better than those described above, and the instrument, from its size, was slow in operation, the experiments have not been carried further.

The Bache telescope described above has proved an extremely convenient instrument for various purposes. Besides the spectroscopic researches already mentioned, several other investigations have been undertaken with it. Owing to its short focal length, it possesses many advantages over photographic telescopes of the usual form. With exposures of an hour and a half, more stars were photographed in the Pleiades than are given in the engraving accompanying the "Annual Report of the Paris Observatory of 1886," although that work was based on photographs taken by MM. Henry with exposures of three hours, and a telescope having an aperture of 13 inches. Nearly twice as many stars were photographed in this region as were visible with the 15-inch telescope of the Harvard College Observatory. The short focus of the telescope also gives it especial advantages for photographing nebulæ. Twelve new nebulæ were thus discovered in a region where but eighteen were known before. Various other investigations, such as a determination of the law of atmospheric absorption, have been undertaken with the aid of this telescope. It has been so persistently used in spectroscopic work that the other researches have been neglected, especially those in which very long exposures were required. Its removal to Peru now cuts it off for some time from such use on the northern stars. Accordingly, Mrs. Draper has procured a similar lens, which is now in the hands of the firm of Alvan Clark & Sons for retouching and mounting. Several important researches will be undertaken with this instrument. Photography is now used in so many departments of astronomy, that a general investigation of the photographic brightness of the stars seems desirable. A plan has been proposed by which a single plate will contain photographs of a number of regions one degree square, but in different portions of the sky. Thus a series of standard faint stars will be photographed, which can all be measured, and reduced to the same scale. One or more photographs of the vicinity of the north pole will be taken on each plate, and thus serve to correct the results obtained on different plates. It is proposed in this way to secure a series of standards of stellar magnitude at intervals of about five degrees. A third lens of similar form, having an aperture of four inches, will be attached to the telescope, with which photographs on a smaller scale, but five degrees square, will be taken simultaneously. These photographs will cover the entire sky, and it is proposed to measure the photographic brightness of all stars of the seventh magnitude, or brighter, which are represented on them. This investigation will have a special value in connection with the photometric measures of the spectra described above. It is hoped also to photograph the entire northern sky by means of the 8-inch telescope, with exposures of an hour. Each plate covers a region nearly ten degrees square, of which the images in the central five degrees square are satisfactorily in focus. One of the regions containing standard stars will appear in the centre of each plate. By such a series of plates the photographic brightness of any stars brighter than the fifteenth magnitude can be determined on a uniform scale. The faintest stars photographed will be nearly a magnitude fainter than the limit proposed by the Astro-photographic Congress, so that all plates included in that work can be reduced to a uniform system. The advantages of such plates for studies of the distribution of the stars and other similar investigations are obvious.

From the above description it appears that the field of work of the Henry Draper Memorial, as now extended, is almost boundless. The problems to be investigated relate to the fundamental laws regulating the formation of the stellar system. Questions of such importance should be discussed on a sufficiently large scale, or the results of the discussion will soon be superseded by a repetition of the work. The liberal provision made for the Henry Draper Memorial permits the investigations to be planned on a scale which is likely to avoid such an undesirable duplication of work.

EXAMINATION AND EDUCATION.[1]

FOR many years I have watched the examinations of young men in our colleges, with reference to the award of prizes and honors, and also with reference to the terms of admission to college and the conditions of bestowing academic degrees. The conclusions to which I have come are these: —

Daily marks, jotted down by the instructor at the close of an exercise, help him to form an accurate notion of the fidelity of his scholars and of their intellectual growth; but it is usually best for him to keep these marks private, and simply for his own guidance, lest by showing the record to his pupils he should accustom them to the notion that work is over when they have learned the lesson, solved the problems, or written the exercises acceptably. He must not teach them to read for marks, — an odious habit.

Examinations held at frequent intervals, say once a month, three or four times a year, or at the end of a certain obvious block of work, especially if preceded by a brief and spirited review, are as serviceable to the scholar as to the teacher. The true condition of a class can thus be ascertained and recorded. The scholar or his advisers can be informed whether or not he excels, is passable, or is deficient. The good students are thus encouraged to better work: the poor students are warned before it is too late to recover their standing.

Yearly examinations accustom the scholar to hold on to the knowledge that he has acquired. If rightly conducted, they remind the pupil that he must carry in his mind the general principles and the fundamental facts of the subject he has studied. A good examiner will put very different questions at an annual examination from those he would set at the end of a month's study. He will endeavor to ascertain whether the subject taught has been mastered by the individuals examined, not whether every detail can be instantly recalled.

Special examinations at marked epochs in an education — such as admission to college, competition for prizes, and the attainment of a degree — encourage young men to put forth their highest and best efforts, to make strong exertions, to overcome great difficulties. As an important part of the business of life is the overcoming of obstacles, so a good school or college should train its pupils to meet and master tasks that are hard. The well-trained youth will not shrink from such difficulties as he must encounter when he becomes a physician, a lawyer, a statesman, a teacher, an engineer, a philanthropist, an editor, a man of business; in short, when he takes an active part in the affairs of life.

In selecting men for high stations, for appointments by the government, or for college fellowships, or for the position of teachers, other tests than those of an examination must be employed. Evidence that the candidate has exact knowledge, and that his knowl-

[1] A contribution by President D. C. Gilman of Johns Hopkins University to he American Supplement to the Nineteenth Century for March.